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DESIGN OF A PASSIVE TRACKER TEST GENERATOR (PTTG) FOR USE WITH DIFAR-LIKE TRACKERS

D Ream

15 January 1979
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METRIC CONVERSION TABLE

From	To	Multiply by
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foot	metre	3.048×10^{-1}

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Passive sonar systems recently introduced into the Fleet require routine performance testing at the Fleet Operational Readiness Accuracy Check Sites (FORACS). Instrumentation for testing DIFAR trackers did not exist at FORACS. This effort was undertaken to provide a prototype model for a dedicated test instrument that could be incorporated into the existing FORACS equipment suite and test procedures.

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OBJECTIVE

Design an inexpensive Passive Tracker Test Generator (PTTG) and operationally straightforward test system for use with existing Fleet Operational Readiness Accuracy Check Site (FORACS) equipment in the testing of submarine and surface ship sonar. The PTTG generates frequency formatted signals for use in the testing of passive, frequency line tracker-type systems that require simulated doppler targets.

Because of the target frequencies and slow simulated speeds involved, it is necessary that highly accurate and stable tonals with very low step (sweep) rates be generated for relatively long periods of time. However, for use with surface ship passive sonars, it is also necessary to operate in the higher frequency and sweep rate areas. There was no commercially available equipment that would meet all of these requirements or lend itself to inexpensive modification.

RESULTS

The PTTG consists of two basic pieces of equipment. The first is the in-house designed and fabricated controller unit. This totally digital instrument is used to encode the desired target characteristics. These include the frequency step rate, step size, the start and end frequency points, up or down sweep direction, and completely automatic or single step manual modes of operation. Targets of known relative speed or acceleration can be generated by selecting the appropriate doppler shift over the frequency range and time period of interest. The controller strobes a five-digit BCD control word into the second unit of the PTTG, a frequency synthesizer. This piece of equipment can be one of several commercially available programmable units. The control word programs the synthesizer for the desired sine-wave output at any given instant. This analog output then goes into an external power amplifier/underwater transducer system for transmission into the water. This equipment configuration can be used at the fixed FORACS locations.

The PTTG is also configured as a totally portable test set for use during pierside testing. The controller, synthesizer, and a small, 60-watt, dual-channel power amplifier are packaged in a metal transit case. If necessary, a separate case houses a battery pack and ac-to-dc inverter to provide portable power. A low power, low frequency projector and associated cable are also provided for transmitting to the ship's underwater acoustic sensors.

RECOMMENDATIONS

- Replace random logic controller with microprocessor based controller. This would allow for direct input of sound velocity and target characteristics in either frequency or relative-speed format. The microprocessor based controller also provides the capability for storing in a memory several test configurations available by operator selection. A reduction in integrated circuits by 80% and in cost by 50% is expected.

- Incorporate an original equipment manufacturer (OEM) frequency synthesizer into the controller chassis. Reduction of cost, interface components, and size are expected to result.

PTTG TECHNICAL DESCRIPTION

The PTTG controller is designed using transistor-transistor logic (TTL) low-power integrated circuitry. The unit is wirewrapped and housed in a 19-inch rack-mounted chassis, 15 inches deep, with a 3 1/2-inch panel height. Front panel target formatting is accomplished by the use of digitally coded thumbwheel switches. The instrument control switches are of the solid-state pushbutton, Hall effect type so as to eliminate switch bouncing and false triggering problems. A five-digit, light emitting diode (LED) type display readout indicates the output frequency at any instant. Interface to the synthesizer is provided through a 37-pin connector.

Referring to figures 1 and 5, the assumption is made that the unit is in the automatic (AUTO) mode of operation and the desired parameter values have been set into their respective thumbwheel switch assemblies.

Upon operation of the SYSTEM RESET pushbutton switch the following sequence occurs:

1. The OUTPUT FREQUENCY counter is loaded with the preset value of the START FREQUENCY by the LOAD pulse.
2. STEP TIME and STEP SIZE counters are set to zero by the CLEAR pulse.
3. The 1-second step timer clock is turned OFF.
4. The START FREQUENCY is displayed on the readout.
5. The BCD control word for the selected START FREQUENCY is strobed into the synthesizer unit by the STROBE pulse.

This sequence initializes the controller prior to actual test operation. At this point, a constant tonal frequency equal to the selected START FREQUENCY will be output from the synthesizer.

If the AUTO START pushbutton switch is now depressed, the following things will happen:

1. The AUTO RUN LED front panel indicator is turned on.
2. The 1-second clock will be turned on and input to the STEP TIME 3-decade counter. The counter will accumulate a count at a 1-second rate. This count will continuously be compared in a 3-decade comparator network with the preset STEP TIME thumbwheel switch value. When these two numbers are equal, a START pulse is generated that turns on the 1-MHz clock and also initiates a CLEAR pulse to reset the STEP TIME counter to zero again.
3. The output of the 1-MHz clock is now input to both the STEP SIZE and OUTPUT FREQUENCY counters. The OUTPUT FREQUENCY counter is of the bidirectional type that will count up or down from the preloaded value. The count direction is determined by the position of the STEP DIRECTION front panel switch. Assume that this switch is in the UP position. The five-decade OUTPUT FREQUENCY counter will now count up at a 1-MHz rate from the previously loaded START FREQUENCY thumbwheel switch selected value.
4. At the same time, the three-decade STEP SIZE counter will be accumulating count at the same 1-MHz rate. A three-decade comparator network will continuously compare the counter value to the preset STEP SIZE thumbwheel switch value. When these two values are equal, a STOP pulse will be generated that turns off the 1-MHz clock. A CLEAR

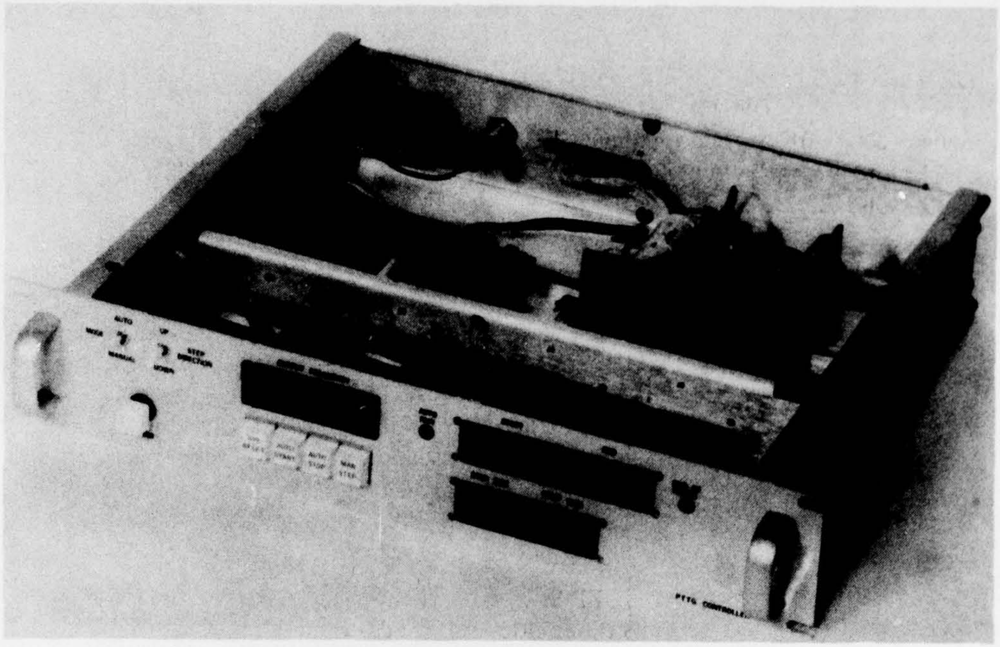

Figure 1. PTTG controller unit.

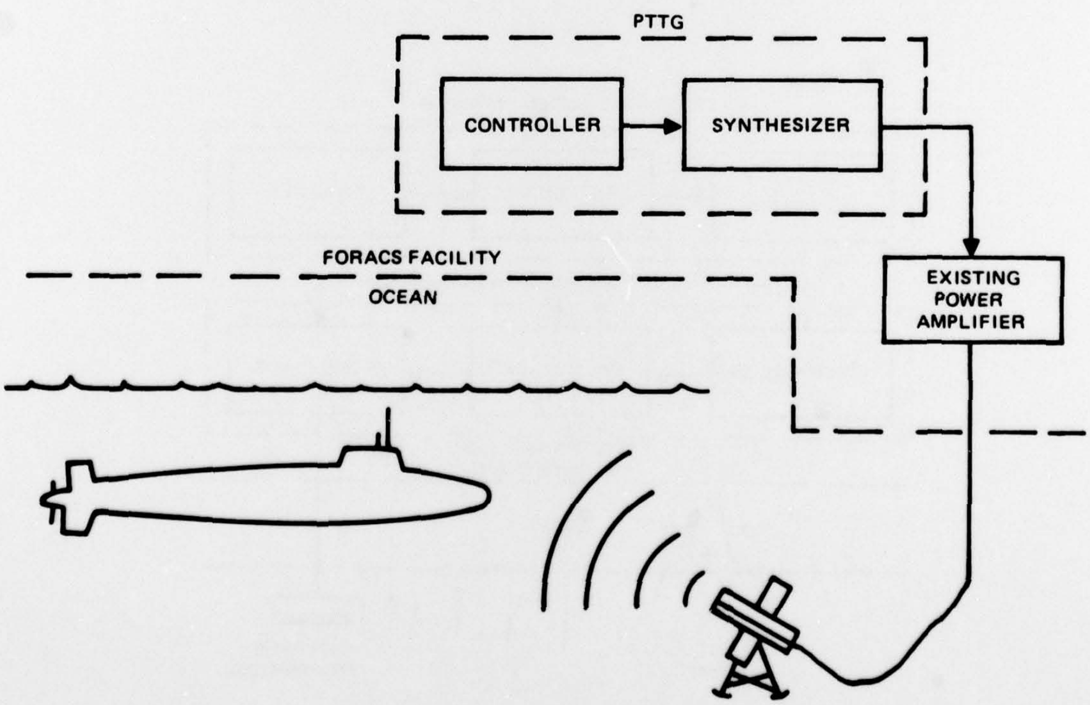

Figure 2. Fixed facility configuration.

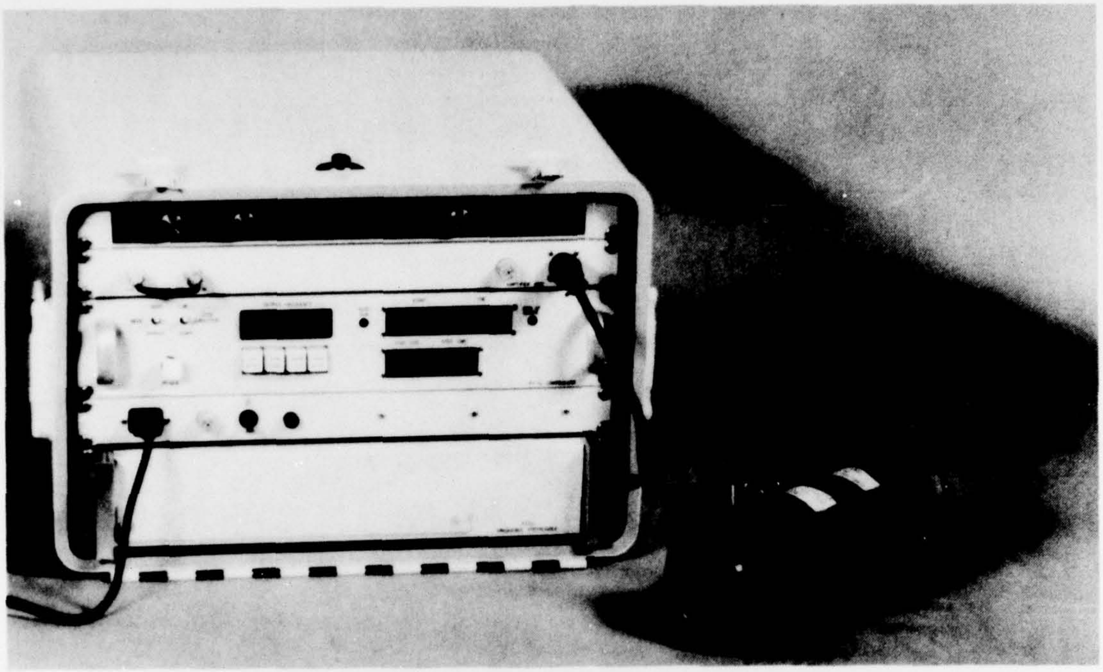

Figure 3. PTTG portable configuration.

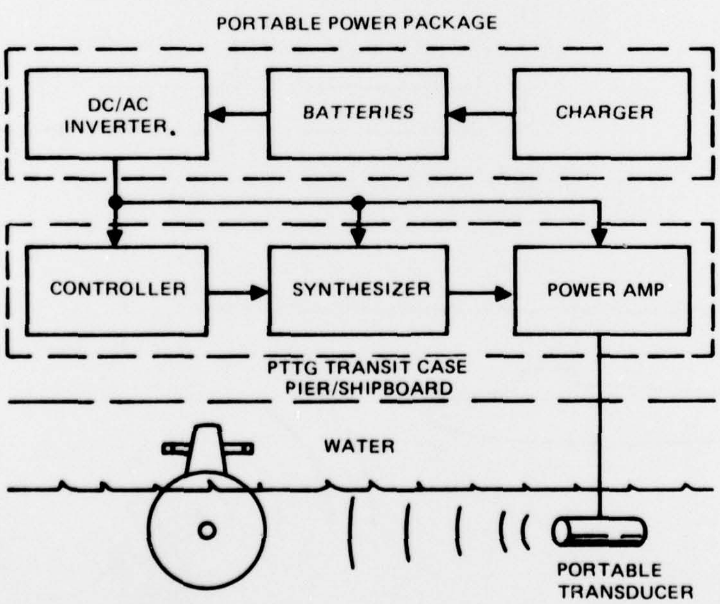

Figure 4. Portable test set configuration.

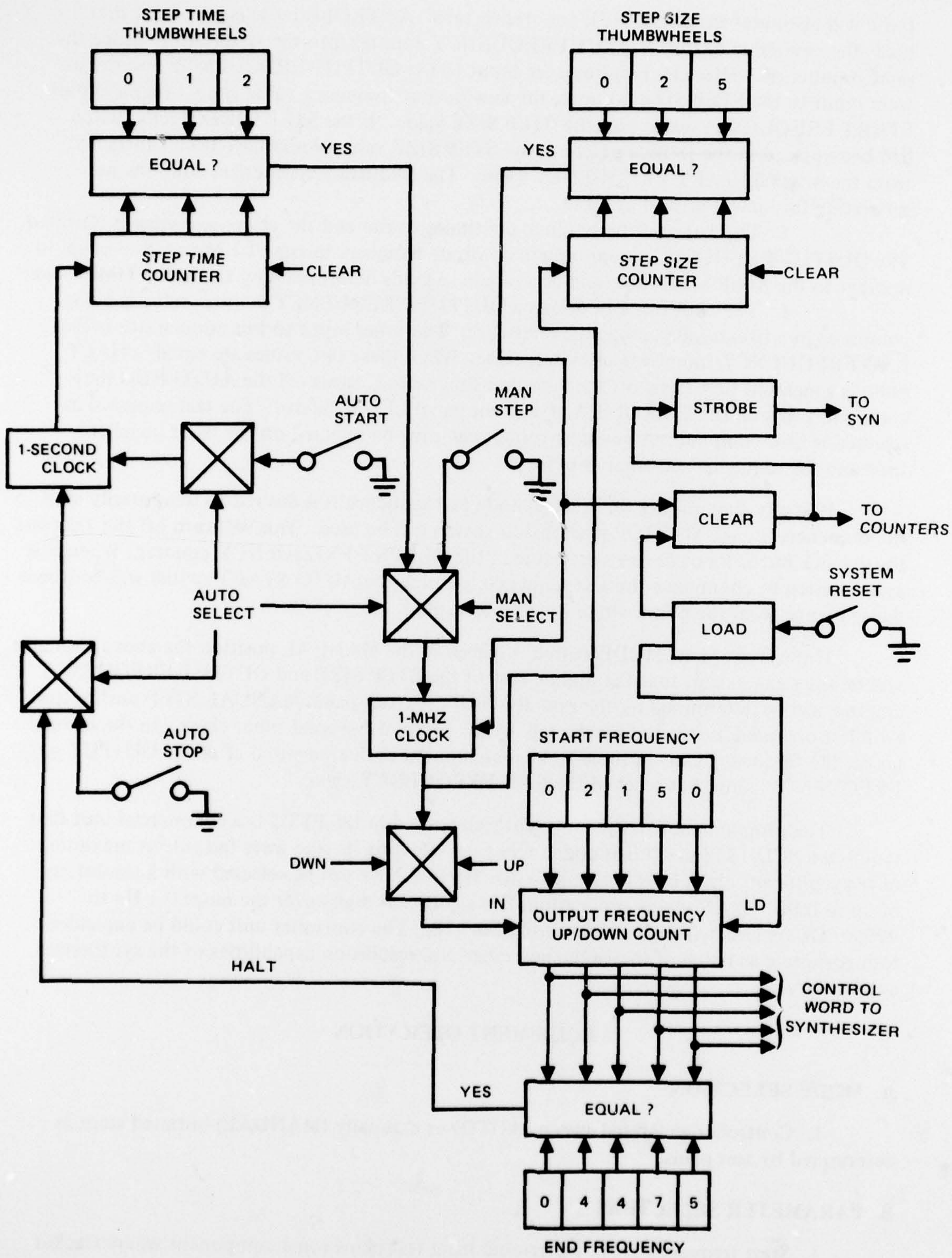

Figure 5. PTTG controller block diagram.

pulse will also reset the STEP SIZE counter to zero. A STROBE pulse is generated that loads the new value of the OUTPUT FREQUENCY counter into the synthesizer. Since the same number of 1-MHz clock pulses were input to the OUTPUT FREQUENCY counter as were input to the STEP SIZE counter, the new output frequency value is the original preset START FREQUENCY value plus the STEP SIZE value. If the STEP DIRECTION switch had been placed in the DOWN position, the STEP SIZE value would have been subtracted from the original START FREQUENCY value. The frequency synthesizer will now be generating this newly arrived at value.

5. The 1-second timer clock continues to run and the above sequence is repeated. The OUTPUT FREQUENCY counter will continue to accept bursts of 1-MHz pulses equal in number to the STEP SIZE value and at a rate in seconds determined by the STEP TIME value.

6. The continuously updated OUTPUT FREQUENCY counter value is being compared in a five-decade comparator network. The other input to this comparator is the END FREQUENCY thumbwheel switch value. When these two values are equal, a HALT pulse is generated that turns off the 1-second timer clock, turns off the AUTO RUN indicator and turns on the END OF RANGE front panel LED indicator. The test sequence as selected is now complete. A new test format can now be selected on the front panel controls and the sequence activated as before.

If at any time during the AUTO mode test sequence it is desired to temporarily stop the sequence, the AUTO STOP pushbutton switch can be used. This will turn off the 1-second timer clock but will not destroy the value in the OUTPUT FREQUENCY counter. When it is again desired to commence the test sequence, pushing the AUTO START switch will continue the sequence from the point where it was interrupted.

If the front panel MODE switch is placed in the MANUAL position the above sequence will be the same except that the update rate of the STEP SIZE and OUTPUT FREQUENCY counter will be determined by the rate at which the front panel MANUAL STEP pushbutton switch is operated, instead of by the rate of the internal 1-second timer clock. In the manual mode, the frequency can continue to be incremented or decremented after the OUTPUT FREQUENCY count has reached the END FREQUENCY value.

The programmable frequency synthesizer used in the PTTG is a commercial unit that required a BCD 1248 multidigit coded word for selecting its sine-wave output. A maximum of ten significant digits over the range 0.001 Hz to 2 MHz can be selected with a resolution of up to 0.001 Hz. For this application, five significant digits over the range 0.1 Hz to 9999.9 Hz are selected with a resolution of 0.1 Hz. The controller unit could be expanded to incorporate as much of the frequency range and resolution capabilities of the synthesizer as necessary.

EQUIPMENT OPERATION

A. MODE SELECTION

1. Controller generated sweep (AUTO) or manually (MANUAL) initiated steps as determined by test plans.

B. PARAMETER SELECTION

1. Start frequency (fo): Determine from test plans tonal component where tracker will start, and set into START thumbwheel switches.

2. Step size (Δf): Determine from test plans step velocity (Δv) increments desired. Then calculate the required Δf necessary to simulate the desired velocity increments ($\Delta f = (fo)(\Delta v)/C$.) Set Δf into the step size thumbwheel switches. The minimum fo that can be generated for any particular doppler speed is a function of the minimum resolution of the controller unit, ie, 0.1 Hz. If it is found necessary to go lower in frequency for very small simulated doppler speed the resolution of the controller can be increased. Example of range of doppler speed simulation for C=5000 ft/sec.:

Δv(kt)	Minimum fo (Hz)
2	160
4	80
6	50
12	25
18	16
24	12
30	10

C. STEP TIME (Δt)

1. Determine from test plans the time period (Δt) over which it is desired to increment Δf. Set the value into the STEP TIME thumbwheel switches. If a common factor exists in the expression $\Delta f/\Delta t$, the step size and the step time can be reduced accordingly. The step time setting applies to AUTO mode only.

D. END FREQUENCY

1. Determine from test plans the frequency at which it is desired to end the stepping function. Set this value into the END FREQUENCY thumbwheel switches. The end frequency setting applies to AUTO mode only.

Example:	C = 5000 ft/sec (3000 kt)	from velocimeter
	fo	from test plans
	Δv = 6 kt	from test plans
	Δf = 0.4 Hz	from calculation
	Δt = 10 sec	from test plans
	f	from test plans

Δf and Δt may be reduced to 0.2 Hz and 5 seconds respectively per step time discussion.

At this point the unit is ready to generate the target signal as determined. Once activated, the unit will start generating a tonal at fo, increment 0.4 Hz (0.2 Hz) every 10 seconds (5 seconds), and automatically stop when it reaches f.

The simulated target acceleration is: $a = \Delta v/\Delta t = 6$ kt/10 sec = 0.6 kt/sec.

For tactical target simulation, smaller Δf or larger Δt would probably be used to simulate more realistic acceleration rates.

For range testing, larger Δf or smaller Δt would probably be used in order to cover the total frequency range of the tracker in the minimum time possible.

SYSTEM SPECIFICATIONS

The specifications for individual units are as follows:

A. CONTROLLER UNIT

1. Frequency:

a. Controlled output range	DC–9999.9 Hz
b. Resolution	0.1 Hz throughout range
c. Selectable step size	0.1–99.9 Hz in 0.1 Hz steps

(Note: The above specifications can be extended to 0.01 or 0.001 Hz if necessary.)

d. Time between steps	1–999 seconds
e. Sweep rate error	less than 0.5%

2. Operating Modes:

a. Automatic or manual frequency stepping
b. Up or down sweep direction
c. Preset start and end of frequency range

3. Controls:

a. Auto/Man frequency step
b. Start frequency select (fo)
c. End frequency select (f)
d. Step size (Δf)
e. Step time (Δt)
f. System reset
g. Auto mode start
h. Auto mode stop
i. Manual mode single step

4. Indicators:

a. Frequency output display (5 digits)
b. Auto mode run
c. End of range

5. Outputs:

a. Five-digit BCD 1248 coded control word to synthesizer

6. Circuitry:

a. Totally digital; low-power TTL

7. **Power Requirements**:

   a. 115 Vac, 50–60 Hz; 16 watts

B. SYNTHESIZER UNIT

(Note: This unit can be any of several commercial models; the unit currently being used is the Rockland Model 5100.)

1. **Frequency**:

a. Output range	dc–2 MHz; ± 0.5 dB
b. Resolution	0.001 Hz throughout range
c. Accuracy	± 1 part in 10^6 per year
d. Temperature stability	$\pm 2 \times 10^{-8}$/°C; 0°C to 50°C
e. Waveform	sinewave
f. Harmonic components	–55 dB
g. Output level	10 Vrms max.

2. **Remote Programming**:

   a. BCD or Binary (10 digits possible)

3. **Circuitry**:

   a. Digital with analog output

4. **Power Requirements**:

   a. 115 Vac, 50–60 Hz, 65 watts

C. POWER AMPLIFIER (PORTABLE CONFIGURATION)

1. **Crown Model D-60 Dual Channel Audio Amplifier**

a. Frequency response	35 Hz to 15 kHz; –3 dB
b. Power output	30 watts continuous into 8Ω per channel
c. Circuitry	solid state
d. Power requirements	115 Vac, 50–60 Hz, approx. 75 watts

D. TEST TRANSDUCER (PORTABLE CONFIGURATION)

1. **NRL Type J9 Projector; magnetostrictive**

a. Frequency range	40 Hz–20 kHz
b. Minimum transmitting response	118 dB//μPa/V

E. POWER PACK (PORTABLE CONFIGURATION)

1. **EICO 1080 Solid State Inverter/Charger, 220 Watts Continuous**

2. **One Eagle-Picher CF12V30 Rechargeable Gel-type Battery, 12 V dc @ 30 A-Hr**

   (Note: Power pack will allow the use of the PTTG at 20 watts input to the projector for approximately two hours.)

F. INTERCONNECT CABLE (PORTABLE CONFIGURATION)

1. One each 100-ft section of underwater cable with connectors.

2. Two each 100-ft sections of waterproof cable with connectors for routing to sonar spaces on test ship. This will allow possible placement of target electronics adjacent to sonar system readouts.

G. OVERALL TARGET SPECIFICATION

1. Frequency:

	Dockside (portable) Configuration	Range (fixed) Configuration
range	40 Hz–10 kHz	200 Hz–3.5 kHz
resolution	0.1 Hz	
step size select	0.1–99.9 Hz	
time between step selection	1–999 seconds	
sweep rate error	less than 0.5%	
accuracy	± 1 part in 10^6 per year	
temperature stability	± 2 $(10)^{-8}$/°C, 0–50°C	
harmonic components	-55 dB	

2. Source Level (Maximum Mean)

Dockside (portable) Configuration	Range (fixed) Configuration
40–2000 Hz	100–400 Hz
149 dB//μPa	154 dB//μPa
2000–10000 Hz	400–1000 Hz
145 dB//μPa	172 dB//μPa
	1000–2500 Hz
	180 dB//μPa
	2500–3500 Hz
	174 dB//μPa

CONCLUSION

A. The Passive Tracker Test Generator was successfully tested pierside, September 1976.

B. Benefits of approach taken:

1. Minimum expenditure in time and cost
2. Resulted in equipment dedicated to passive tracker testing.
3. Ease of operator set-up.
4. Flexible for various operational requirements
5. Uses readily available parts and commercial equipment with minimum in-house fabrications. Results in controller section that could be easily fabricated on a printed circuit board.
6. Frequency synthesizer chosen over analog voltage controlled oscillator (VCO) because analog VCOs generally have accuracy ratings on the order of 0.1 to 1%

of full scale. This rules out a single VCO with digital-to-analog control to cover the entire dc to 10 kHz frequency range. Multiple VCO or mixer circuitry could be developed to cover the entire spectrum within the accuracy and resolution requirements. This is not considered cost effective, however, when compared to the use of extremely accurate and stable stand-alone or OEM-type frequency synthesizers now available.